

## Research Article

# Implementing Lean Practices: Managing the Transformation Risks

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Insightful implementation of lean is necessary for high-value manufacturing and is complementary to strategic decision making regarding manufacture. However lean can be difficult to implement in specific organisations. One of the difficulties is deciding which of the many lean tools to apply and when to apply them. A complicating factor is change management. Lean implementation is a transformational process and needs to support organisational development alongside process improvement. We develop a method based on risk management to identify which lean tools are most appropriate for a specific organisational setting. This permits the situational and contingency variables to be accommodated in the lean transformation. The method is demonstrated by application to a small manufacturing organisation with a high-variety low-volume business model. Thus it is possible, given contextual knowledge of the organisation, to predict which lean methods are most important in the situation. This enables the prioritisation of organisational effort towards lean methods that are relevant to the organisation at that particular time in its development.

## 1. Introduction

Lean is considered an essential attribute of a successful manufacturing endeavour [1]. The underlying principle of minimisation of waste for maximisation of productivity has become profoundly influential since being developed into the lean construct [2–4]. As lean has matured, it has been applied ever wider [5, 6]. This includes industries other than manufacturing and into manufacturing industries that were not natural early adopters. It is this latter category that is the focus of the present paper.

There is no doubt about the general relevance of lean principles. However the implementation in specific organisations is not straightforward and is not always successful. Sometimes this is because the principles were sound but the implementation failed [7–9], that is, a change management problem. But in the more general case, removing change management issues from consideration, there is still the difficulty of deciding which of the many lean tools to apply in the situation. This is important because lean includes many methods, and the relevance thereof is situationally specific. Implementing lean therefore requires some specific decisions, and the outcome has an element of risk: the implementation

could succeed or fail. Unfortunately there are no specific tools for the selection and prioritisation of methods during implementation.

This paper explores the implementation of lean, with a particular focus on the choice of lean tools that are relevant to specific situations. We apply a risk management perspective, in the sense that the implementation of lean can be an opportunity for the organisation (if implementation succeeds) or a threat (failed implementation and wasted organisational effort, and resistance against future attempts). Thus we explore the intersection between strategic risk management and lean implementation. We show how risk considerations can be built into a method that can help identify which lean tools are most appropriate for a given situation. We close with a case study demonstrating the method for a small manufacturing organisation.

## 2. Existing Approaches to Lean Implementation

Lean implementation involves selecting appropriate tools from the lean arsenal to achieve process excellence. However

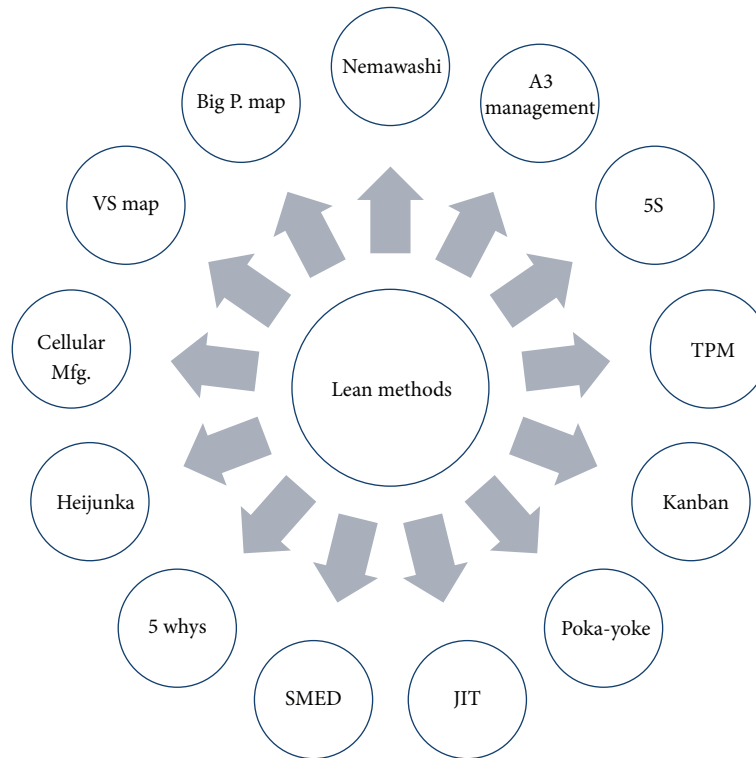


FIGURE 1: Lean methods or tools: a selection of some (not all) of lean methods indicating the importance of having a selection criteria and prioritisation method for implementation.

there is a danger of focusing overly on the tool benefit and striving for process excellence but neglecting the sustainability of the lean tool within that specific work culture. Every time a new method is implemented there is risk introduced to the organisation: both an opportunity and a threat. On the one side is the benefit of the technique and on the other side are the detriments. Relevant questions are:

- (1) What is the benefit of the lean technique under consideration and how likely or difficult is it to achieve? (Is it worth doing this?)
- (2) How do the usage of the lean technique and its benefits relate to the sustainability of the change intervention? (Would doing this have long-term benefits?)

In this paper we are particularly interested in the situational applicability of lean tools and specifically the organisational decision making that precedes the implementation of lean. There are three issues: which of the many lean tools to implement in a specific situation; how to make a balanced evaluation of the risks (opportunities and threats) for each candidate tool; and how organisational culture affects the success (or otherwise) of the change management implementation.

**2.1. Lean Management, Its Principles, and Methods.** Lean is a strategy developed for production improvement. It originated in the mass production setting of the automobile industry, specifically the Toyota Production System. It is primarily

focussed on the minimisation of waste of any form [2, 3, 5, 7]. When wasteful action is eliminated the result is that less effort, space, and capital are required and lead time is reduced whilst quality increases and the cost of quality decreases [5, 10]. From its manufacturing roots, lean has subsequently expanded to business practice generally [11, 12]. Lean management is becoming the standard for systematic productivity improvement [1].

**2.1.1. Lean Tools.** Superficially, lean comprises a set of tools and techniques (kanban, 5S, TPM, SMED, etc.), and the naive implementation decision is simply which tools to implement. Figure 1 illustrates the multiplicity of tools available. Work has been done on the classification of tools [13–15] and the relevance of tools to specific wastes [16]. These go part way to addressing the problems with implementation, but situation specificity has not been achieved; that is, it is still not possible to identify which tools are most appropriate in which situation. Consequently practitioners frequently lack the means to make informed decisions about which tools to implement in their situation.

**2.1.2. A Typical Implementation.** A typical lean implementation involves an initial value stream mapping (VSM) which defines the journey of improvement. Next there is the organising of the house. This might involve flexible work systems and (especially) 5S (sorting, straightening, systematic cleaning, standardizing, and sustaining). Thereafter other specific

tools are implemented as relevant. These include standard work, single minute exchange of dies (SMED), total productivity maintenance (TPM), and mistake proofing (Jidoka). Further advancements might involve supply and demand, through just in time (JIT) pull systems and Heijunka (level scheduling) [17]. Also relevant is the integration between lean and production planning and control systems such as materials resource planning (MRP). This is not always easy due to the lean emphasis on pull, whereas the reality is that many manufacturers benefit from hybrid production flow control [18]. Systems are being developed to operationalise this [19], though a detailed explanation is beyond the present scope.

Therefore weaknesses in a typical lean approach can be in fixation on tools as an end in themselves. This promotes isolated improvement rather than optimisation of the entire production system and an incomplete appreciation of the role of leadership for organisational development.

**2.1.3. Organisational Culture and Change Leadership.** In the context of organisational change we look for methods that will support sustainability, that is, obtaining enduring benefits. The decision to implement lean is typically a decision of senior management, that is, a top-down change initiative. While there are many models of the change management process [20–24], the process is not always as successful as intended [25, 26]. As change management shows, abrupt changes result in resistance [21, 27, 28]. At the deeper level lean is a culture, that is, a set of organisational attitudes, rather than a mere use of tools [29, 30]. The sustainability depends on organisational culture and the collective response to the change. Furthermore, many of the lean tools are sophisticated in their requirement for a particular type of culture, including strong intrinsic motivation at the shop-floor level for the processes (e.g., kaizen, 5S, quality circles, work cells, and six sigma). Thus implementing lean requires a change management process that fosters the outcomes, hence *change leadership* through coaching [21, 27] as opposed to merely directive top-down change. In a lean system the *respect for humans* principle is equally important as the elimination of waste [2, 11]. Lean is commonly associated with the latter and the respect for humans component is largely neglected. True lean involves a focus on the people of an organisation, creating a culture that empowers staff at all levels to make innovative changes that improve productivity by reducing wasteful action (*muda*). This creates dynamic and flexible learning organisations of emergent change [7, 31, 32]. Efficient and effective communication processes enable collaboration and consensus along with shared vision and engagement [7, 32]. In this way “respect for humans” works synergetically with and for “waste elimination.” Neglecting the human component jeopardises the sustainability of the change and makes it difficult to reach the level of cultural excellence for continuous improvement [7, 8, 30]. A popular representation of this is the *iceberg model* of Hines et al. [7], with the lean tools, processes, and techniques being the visible component above the waterline, with the unseen supporting functions being strategy, leadership, and employee behaviour and engagement.

This introduces a time dimension to the implementation, since culture is not instant. Consequently it may be necessary to *build* that culture. Specifically, lean is implemented in stages over time, by selecting tools that are appropriate to the organisation at that point in time. It may be wiser to first implement simpler methods with the view of engagement and acceptance of staff as opposed to attempting to immediately introduce the more complex lean tools. These become small “wins” that build momentum and staff confidence [7, 27, 28]. Employees need to be engaged to support a difficult method (like JIT). Thus, even though certain lean tools may hold the promise of high returns, they may also be risky to implement. Failure could ruin future chances of success and engagement.

Implementation of lean is therefore an organisational strategy regarding the changing of culture over time, by the selective and progressive implementation of lean tools that are situational relevant for that organisation at that time, followed by further implementation later when the culture has caught up. Practitioners typically describe this deliberate temporal progression as the *lean journey* [7, 12, 33]. Thus the concept of continuous improvement (CI) applies not only to the technical operations but also the strategic implementation at organisational level. The residual difficulty is that of *deciding* which lean tools are relevant for the organisation at that point in its journey. This is a question to which we return, and in the next section we show how consideration of organisational *risk* can lead to a solution.

**2.2. Risk Management.** All ventures that an organisation undertakes have risk, that is, uncertain opportunity and threat. The risk management (RM) methods encourage a deliberate and integrated consideration of both these outcomes. Various standards have defined risk in the sense of both negative and positive aspects, for example, [34–36]. Other core concepts in the RM method are the partitioning of the problem into two variables, consequence and likelihood. Thus the analysis task reduces to determining first the magnitude of the outcome, which may be positive or negative, corresponding to opportunity or threat, respectively, and then the likelihood of that outcome. The magnitude of the outcome may be represented quantitatively or qualitatively. Likewise the likelihood may be quantified in a probability or expressed as a subject qualitative statement (very rare...almost certain). These two variables are then combined to give an overall score for the risk. If the variables are all quantitative then a simple product operation is used, but qualitative variables require a mapping process. The process is repeated for several scenarios under consideration and the RM method assists the decision making by identifying the scenario with the highest risk (or lowest as the case may be).

The risk management method is particularly effective for quantitative variables and has therefore found widespread adoption in engineering, finance (particularly insurance), and project management situations. Although the method as a whole claims to be applicable to strategic decision making even at the highest level of the organisation and examples of this are available [37], this is not a particularly well-developed capability of RM.

In lean implementation we are particularly focused on what is desirable in terms of lean success and sustainability and undesirable in terms of failure of the implementation.

**2.3. Intersection between Lean Implementation and Risk Management.** There has been some prior work at the intersection of these two bodies of knowledge. One line of enquiry, although perhaps not risk management per se, has been to identify critical success factors for lean implementation [7, 38–40]. Innovative frameworks and manufacturing techniques, for example, core competency based framework [41] and emergent manufacturing methods [42], have been applied to reduce specific “risks.” The two methodologies have been compared [43] and applications in lean itself have been used to identify and treat uncertainties (risks) in construction projects [44, 45]. Processes including supply chain modelling have been used to support mitigation of risks [46–49]. The applicability of RM in selecting lean six sigma projects has been identified [50].

Regarding the specific question of how to manage the risks in the implementation of lean, there has been work on matching of lean systems strategy to risk identification, using a systems engineering approach [51], and use of project management methods [52]. It has been suggested to merge lean thinking and “high reliability” [53] to balance the nonbuffered, “fragile” nature of lean [54]. There is lack of methods to improve the reliability of lean implementation [55]. In summary, reviewing the literature we found little to no application of a standardised risk assessment to a lean implementation project.

Two other methodologies have some relevance. These are *Agile manufacturing* and *Theory of Constraints*. However neither of these have shown any major integration with risk management, though some movement has been made in that direction examples: for JIT see [56], for TOC see [57].

While the lean and risk management practices each have well-established literature, there is currently no integration between the two. This is despite the fact that the implementation of lean is full of risks: both the opportunities that the managers seek to capture, and the threats and failed implementations that too frequently result.

The purpose of this paper is to develop a methodology for assessing the risks—both the threats and the opportunities—of the lean methods. The particular area of interest is contextual decision-making: we wish to be able to better identify the lean tools that are relevant to specific situations. The area under examination is SME manufacturing firms, because lean is particularly difficult to implement in such organisations. This is worth attempting, for the potential to avoid failed lean implementation, the attendant wasted organisational effort, resistance against future attempts.

### 3. Approach

Our approach to this problem was to reconceptualise the decisions surrounding lean implementation as a risk management problem. We consequently developed a conceptual framework for treating lean in this way. From this we created

a method for assessing the risks of lean practices. Importantly, this method is able to accommodate a specific organisational context. We then applied the method to a case study firm.

## 4. Results

**4.1. Conceptual Model for the Integration of Risk and Lean.** We start with the principles of risk management (RM) and lean. RM has a clear set of principles [35], whereas these are more tacit in lean. We therefore recast the contemporary understanding of lean into a set of principles and then compare and contrast these with those from RM.

The results are shown in Figure 2. The major difference in the function of risk management is to explicitly address uncertainty, whereas lean explicitly addresses wasted effort through the optimisation of flow. Nonetheless there is a clear fit between the principles. Both lean and risk management focus on “value”. The risk approach protects value and lean supports this by focusing on providing customer value. Both are systematic and data driven. Both implementations are tailored to the organisation, take into account human and cultural factors, aim to be inclusive of the entire system (not compartmentalised or locally focused), and include all stakeholders in the processes. Both are dynamic and responsive to change and facilitate continual improvement of the organisation.

Next we compare the frameworks. Again, RM is more organised in this regard and already has a framework and we create a comparative one for lean. To do this we merge the lean iceberg model [7] and the 5 principles of lean [12]. The results are shown in Figure 3.

The lean concepts are synonymous to those of the risk management strategic process. The mandate and commitment of the framework is synonymous with management commitment, strategy, leadership, and alignment within the organisation. This is made more clear from the detailed definition in the standard [35] (cf. [7]). The cycle itself, design, implement, monitor, review, and continually improve, is a simple PDSA (or PDCA). This cycle came out of the quality and continuous improvement field [58, 59] which are consolidated in lean thinking. The five key principles of lean [5] can be shown to relate to the PDSA cycle although possessing specific meaning to lean thinking, that is, defining value and planning for the flow of value with as little waste as possible and the goal of perfection in view.

The final part of the conceptual model is creating an integrated process model. This is achieved by overlaying the lean processes on the risk management process; see Figure 4. The ongoing communication process indicated as key to good risk management is very much a part of continuous improvement and lean. Toyota developed particularly efficient and effective means of communication to allow consensus and collaboration throughout along with the engagement and input from all staff. Techniques such as A3 management, with the *catchball* process or *nemawashi*, are integral to the TPS and lean learning organisations; see [7, 32]. Establishing the context is synonymous to defining value from the customer viewpoint. The context in risk management strictly is both

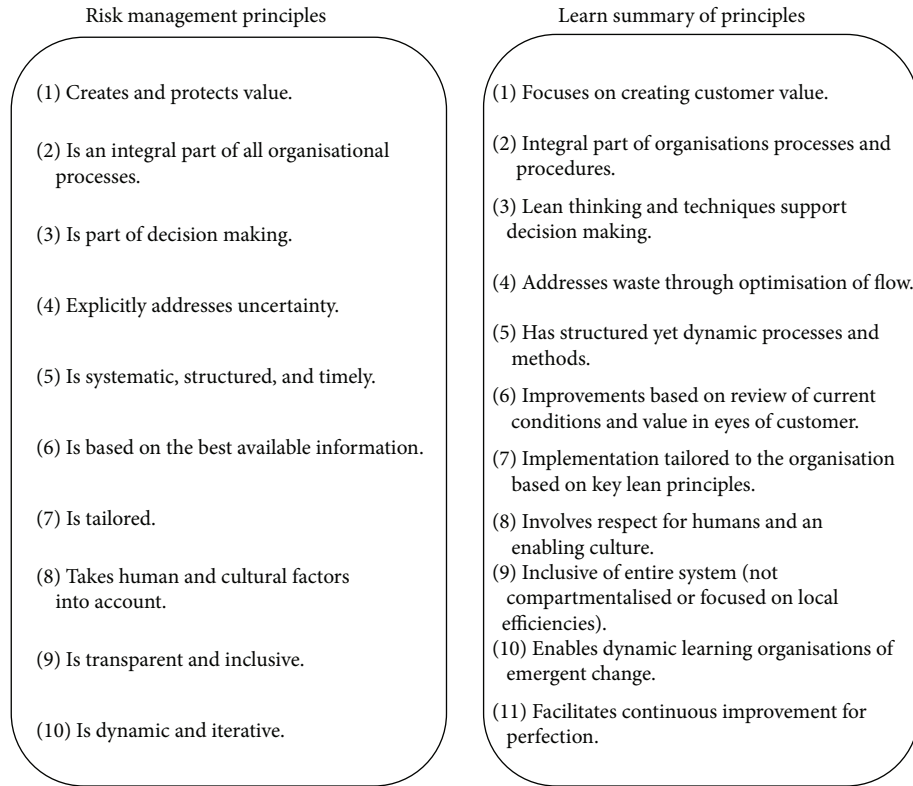


FIGURE 2: Principles of risk management [35] besides recast principles of lean thinking on the right, showing mutually supportive and complementary nature of risk management and lean management.

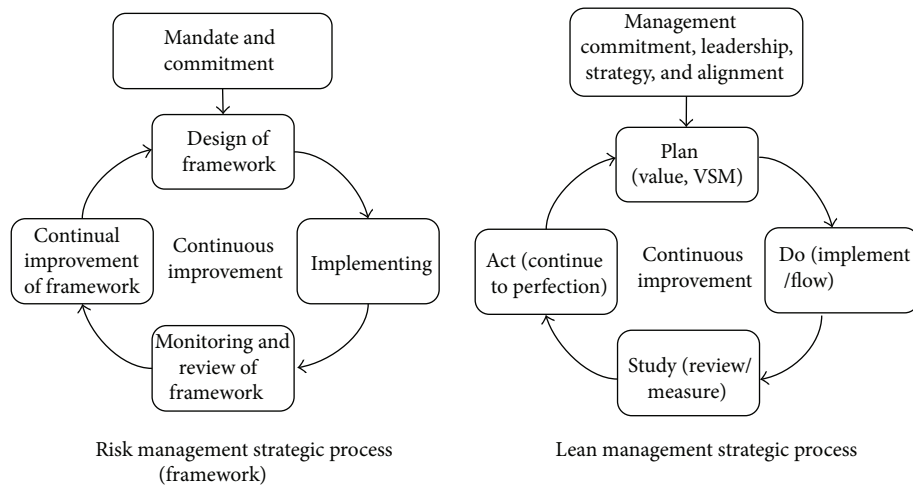


FIGURE 3: Risk management framework [35] compared with lean management.

internal and external looking and so in reality crosses with the mapping of the value stream. For simplicity sake we have included VSM in the risk assessment area, that is, looking at the current state and opportunities for improvements to get to a desired future state. In the assessment analysis step we have identified the 5 whys tool for root cause analysis (RCA). Other tools could similarly be used (e.g., Ishikawa fish bone diagram). Evaluation of risk has been overlaid with A3 management. This an A3 sheet for reporting

and formulating ideas and passing into the communication process for consensus. Risk treatment is the appropriate application of various lean methods chosen through the assessment process. The PDCA cycle is built into the process for monitoring and review.

In some ways it is not surprising that the risk management approach matches with lean management, since both had roots in the quality and continuous improvement systems [4, 6].



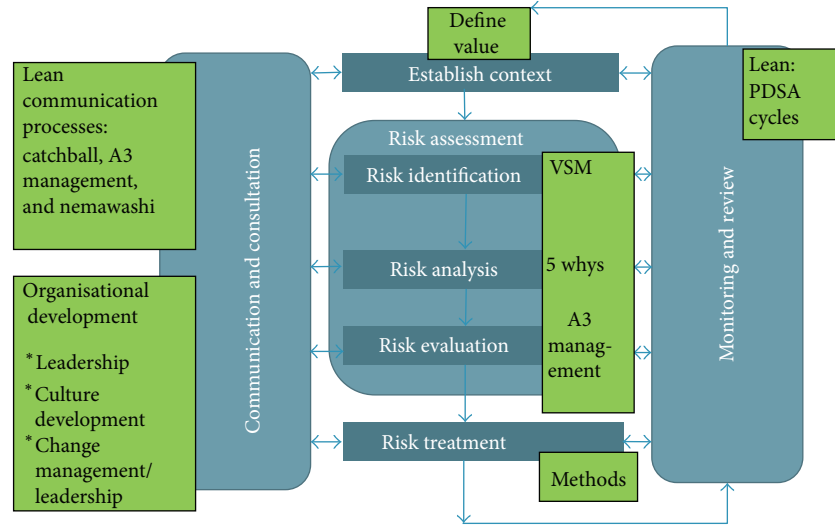


FIGURE 4: Lean processes overlaid on risk management process as per the ISO standard [35].

**4.2. Developing a Mechanism for Implementation.** Having achieved a broad conceptual integration of risk and lean, the next step is to develop an operational method, a mechanism for the application of RM to lean decision making. This needs to be suitable for practitioners. We assume that someone contemplating implementing lean has already acquired background knowledge of various lean tools (see Table 1) and focus our method on supporting the decision-making, identifying the factors that could be considered. We do this by following the risk management process taking particular care to represent the organisational factors, as these are known to be crucial for successful implementation. The results are shown in Table 1.

**4.2.1. Process.** Standard tools for the strategic scanning of risks are PESTEL and SWOT. These are for environmental scanning and identification of risks in the form of internal strengths and weaknesses and external opportunities and threats (hence SWOT) and may be characterised by political, economic, and other variables (hence PESTEL). The integration of these with strategic risk management has already been demonstrated [37]. The strategic risks are primarily qualitative, as opposed to quantitative, and hence a matrix mapping is appropriate (as opposed to quantitative treatment).

We therefore apply qualitative graphical techniques to represent the risk for lean implementation. We plot, as orthogonal variables, the impact of each specific lean tool, and the likelihood of achieving that impact; see Figure 5. In this regard we use *impact* where the RM method uses *consequence*, but the two are comparable. The impact is the effect on the organisation in regard to lean transformation.

The chart aids in identifying where initial wins or easy implementations can be targeted. Note that high likelihood (low difficulty) events can be critical even if the immediate impact is not high. This is because gaining small wins is

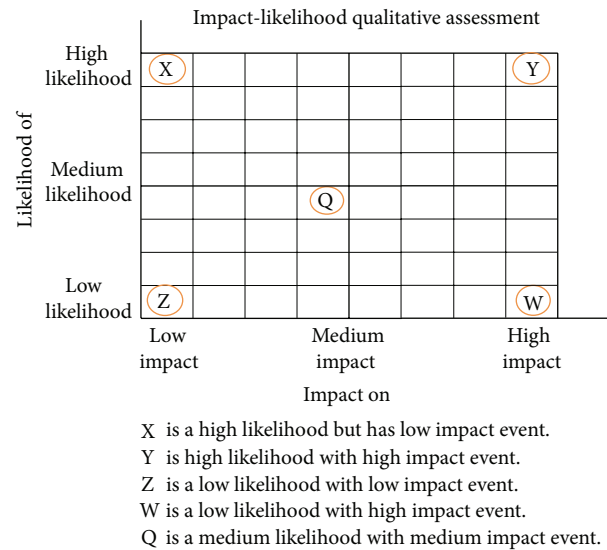


FIGURE 5: Likelihood-Impact qualitative assessment example plot.

particularly important at the outset of an implementation to ensure momentum and sustainability [7, 27, 28].

In summary, we have established a method whereby the implementation of lean can be considered a type of risk, with potential positive and negative outcomes. We have created a method that is able to identify the risk associated with a specific aspect or tool of lean. The next section illustrates the application to a case study.

## 5. Application to Case Study

**5.1. Characteristics of the Firm.** The case study is a small to medium enterprise (SME) that is a make-to-order and design-build manufacturer specialising in complex parts and

TABLE 1: Summary of process for lean implementation risk management according to ISO 31000:2009.

Risk management process AS/NZS ISO 31000	Lean implementation Application
Set context	Lean systems reduce waste activities and increase value to customers, thereby increasing productivity and profitability. Internal context of resources and staff culture and sustaining the change. External context of market conditions.
Perform risk assessment by: (see (1)–(3))	
(1) identification of sources, areas, impacts, and events,	Lean methods have risk associated with their use, benefits, and detriments impacting various areas.
(2a) analysis to understand the risk its causes, sources, (see (2b)) and other pertinent factors,	Qualitative discussion of detriments or risks of sustainability of lean method (source) or entire lean implementation in context of the tools and consequences of tool use.
(2b) consequences and likelihoods, confidence sensitivity, and other pertinent factors,	Expert opinion (qualitative) is incorporated as charts. The chart shows our qualitative assessment of likelihood and consequence for various tools; refer to Figure 5.
(3) evaluation for assisting the decision making process including risk tolerance of parties.	In the context of organisational change we look for methods that will support sustainability. There is a decision from management (a mandate) to support lean to meet business goals but wisdom is required in the lean implementation for building a culture for sustainability. This involves selecting the right methods at the right time. It is necessary to get “wins” in the view of the staff up front. This is not necessarily the biggest wins but small wins to gain momentum and staff confidence. We cannot tolerate high risk even when high return is possible at the start of an implementation that is, where staff are not yet engaged to support a difficult method (like JIT). Failure could ruin future chances of success and engagement. Communication at the start of an implementation, is key to impart the vision and break down goals to give critical steps for change.
Prescribe treatment of risk To maximise benefits and minimise detriments, increase the positive and decrease the negative likelihood and consequences.	Treatments we prescribe in general cover the following: adequate communication with development of new identity for staff; prioritisation of time for business running and improvement activity; and prior conditions met adequately (including previous methods, training of and engagement of staff) for any methods implemented.

assemblies. It is representative of the many SMEs that are actively trying to decide which parts of lean are relevant to them and how to implement them. The firm (“SI”) is based in New Zealand and has 20 employees. Typically production is of small to medium size runs, high-variety low-volume (HVLV). The firm possesses an advanced CNC equipped plant, has precision assembly capability, and takes pride in project management, that is, providing the full solution including concept and design development, build, commissioning, delivery, and after-sales support.

Historically lean has been the preserve of the large high-volume manufacturers typified by the automotive industry. However as the lean method has matured and spread to other industries, it has been applied to smaller and more specialised firms, like that considered here. Lean adoption is also driven by competitive pressure, particularly the opening of global markets and the resulting exposure to more efficient competitors. Therefore even the small firms have to consider how they preserve competitive advantage and deliver value to customers. These firms, being small, typically cannot afford to employ specialised staff for this purpose. They also have limited resources for implementing new programmes like this.

*5.1.1. Strategic Mandate.* In the case of this firm, the need to adopt lean was identified at board level, that is, was

a strategic decision. To compete within the international market the firm needed to show the value of a local supplier by reducing lead time and manufacture costs and developing ability to handle demand variability (e.g., achieving flow and eliminating wasted effort including reducing run setups) as well as increasing quality. Lean methods can be used to treat these areas and therefore lean was considered a strategic priority.

At the strategic level the firm needed to treat key factors for success and sustainability of lean. These factors have been identified [7, 12, 27, 32, 60] and summarised in Table 2.

*5.2. Evaluating Risk within the Lean Strategic Principles.* One of the authors (AP) worked half-time for six months in the firm as part of a government-industry-university partnership. This provided the contextual knowledge for our analysis. We then took each of the strategic principle tools and evaluated, for this firm’s context, the impact and ease of implementation (see Tables 3 and 4). We then plotted these on the risk chart; see Figure 7.

All the principles in this first set are of higher level and seen as critical to lean success and sustainability; however it is important to understand the challenges or level of difficulty faced. In our representative case we see particular areas of difficulty for SI around process flow, for example, flow and value stream analysis and application of pull systems. This

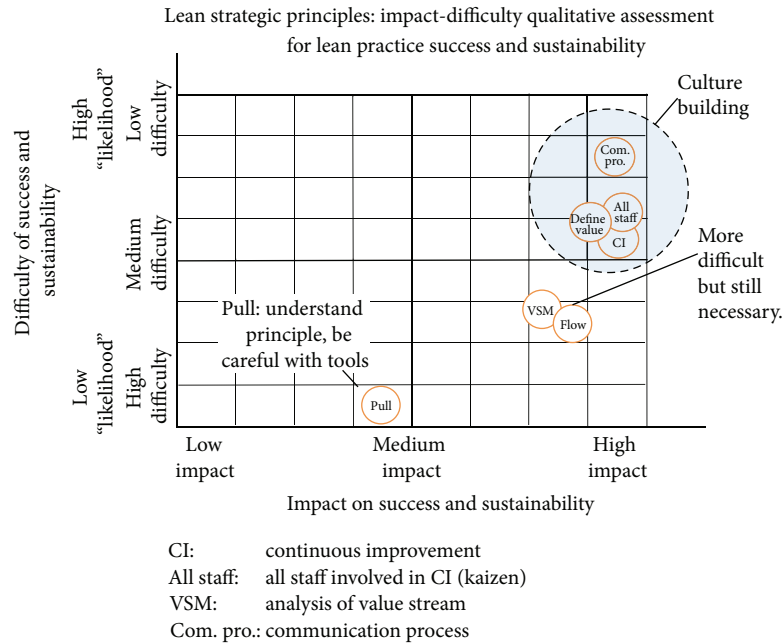


FIGURE 6: Strategic principles: lean key principles and higher order processes qualitatively assessed for impact and difficulty (likelihood) of success and sustainability (reference case SI).

TABLE 2: Lean risk treatment at a strategic level.

Change leadership	Leadership commitment with the vision and its communication for engagement of staff. The initial steps of change and ongoing “wins” for momentum of change. The development of a new organisation identity.
Managing internal resources	Physical, human (availability and capability), and financial resources need to be managed for amounts of training, learning, and implementing changes.
Managing external resources	Use of consultant (sensei) or other external resource for training.
Other factors	Market conditions and forecasts (risk), demand variability, and expected product mix (variety), among others.

is because of the make-to-order nature and complicated processes of their business. This is reflected in the Likelihood-Impact chart for these factors.

In Figure 6 we see the medium level difficulty but high impact of *defining value*, and having all staff involved in enterprise wide *continuous improvement*. Defining value is key to understanding what the customer desires and what wasted effort is that is, what should be eliminated through improvement. The communication process presents the vision of value and continuous improvement to all staff and allows for staff engagement and development of a learning organisation and hence also high impact. This suggests that the big wins for a make-to-order enterprise like SI would be in the culture excellence for continuous improvement and

not so heavily in the process flow tools (although process improvement would occur as a result).

For the same reasons, value stream and flow are assessed as having only medium/high impact in the SI case. In contrast these would have high impact in a continuous production facility.

Pull is very difficult in SI’s case and would need particular adaption as suggested in the table. SI may need to use pull of order to pull paperwork but push material to the process for flow. This would change where higher quantity production permitted and even temporary or isolated flow lines could be introduced.

**5.3. Prioritising Lean Methods: SI Case Study.** There are many different methods or tools of lean. These were each evaluated for the SI case, in a way complementary to the strategic principles. The likelihood and impact of these methods is plotted in Figure 8.

We do not attempt to justify the implicit judgements in Figure 7 whereby a particular method is given the impact and difficulty scores shown. Instead we suggest that this requires a contextual knowledge by the person performing the assessment. In this particular case the first author was seconded to the firm as part of the research project and spent considerable time learning the context in which Shamrock operated. The assessment presented as Tables 3 and 4 provide insight to the process.

The purpose here is to identify small wins (sometimes called “low hanging fruit”) to increase chances of sustainability. Here the tools more applicable to the make-to-order business are featured in the *top right corner*. In contrast the tools for fine improvement of production efficiency,



TABLE 3: Strategic principles: lean key principles and higher order processes risk analysis table (reference case SI).

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(A) 5 Strategic principles					
(1) Defining value	Lean begins with defining value from the customers point of view, that is, what is not value is waste to eliminate.	Gives clear strategic focus based on what the customer is willing to “pay for.”	Requires survey of customers, may challenge traditional thought of what the company should be focusing on and therefore create conflict of identity and resistance.	Take to the required extent only—dependent on size and customer pool and current situation; for example, need to pull in more customers may need wider survey. Be prepared to develop new identity based on outcomes. Training and prioritizing are key. Take only to the extent required for the current state of operations. Involve key persons from functional groups rather than all staff except where key to general training or staff identity development. At Shamrock initially concentrate on information flow (rather than cellular layout) and try to identify core processes for mapping and improvement.	Voice of the customer.
(2) Process/value stream mapping (VSM) (difficult for Shamrock case)	Analysing of processes and waste there in by mapping current and the desired state. Complexity depends on need. In principle start with core process. This, together with defining value, sets the vision and course of action.	Gives a health check on now and identifies key processes or faults with a system. Gives future goal and direction.	Requires training and at higher levels all staff are involved. Can be simplified process where improvements and waste are more obvious but as more detail is required it is an involved and time consuming exercise. This is difficult in the Shamrock case due to the complicated jobbing processes that rarely repeat.	At Shamrock initially concentrate on information flow (rather than cellular layout) and try to identify core processes for mapping and improvement.	Value must be clearly defined.
(3) Flow/one piece flow (difficult for Shamrock case)	Flow is a key concept to lean. It is seen ideal to approach one piece flow. Process flows should be made as visual as possible. Concepts like FIFO are introduced. Lean is “not trying to optimise the utilization of people and equipment but optimise the flow of material;” [2] includes information.	Reduces lead times, makes problems visible (bringing them to the surface) and supports quality at the source (see below under Tools).	Takes skill and training to understand flow and adjust the systems, for example, to make flow logical and visible. Typically involves changing of habits (e.g., FIFO) and takes rearrangement of physical and human resources (e.g., cells). Again this is difficult in the Shamrock case due to the complicated jobbing processes that rarely repeat.	Training in lean “flow thinking”—try reading The Goal [62] and Lean Thinking [12]. Promote to staff the reason why it is necessary and educate them about the benefits of flow. At Shamrock initially concentrate on information flow (rather than cellular layout) and try to identify core processes for mapping and improvement.	VSM done adequately.

TABLE 3: Continued.

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(4) Pull (difficult for Shamrock case)	Process initiated by the customer's order "pull." The goal is to reduce batch size to approach one piece flow/JIT manufacture. See also "JIT" below.	Powerful in reducing waste and lead time. Inventory stores have all sorts of problems (space, quality, damage to stored goods, superseded parts, sales pushing on old stock).	Takes skill and training to understand properly. Promotes a lack of stability because buffers reduced—difficult for job shop and project based style organisations. Again this is difficult in the Shamrock case due to the complicated jobbing processes that do not repeat.	A progression from higher end of flow thinking to ensure flow is well developed. Can use buffers to support stability but not ideal. Use training of staff to overcome resistance (see Flow above). May need to use pull of order to pull paperwork and push material to flow.	Flow
(5) Journey to perfection	Continuous improvement via PDCA (plan, do, check, act cycle) of above steps.	Drives continuous improvement.	Needs Perseverance/sustainability	Build into processes (and culture). Target small wins at the beginning, maintain momentum, and leverage a new staff identity.	Value, VSM, flow
(B) Effective communication processes	Use of A3 management, nemawashi, and catchball—that is, concise reporting and feedback for consensus through simple and effective communication.	Consensus reached, staff engaged, vision shared. All contributing to the one goal and vision.	Development of the process is required e.g., training in A3 management. Sustainability and discipline required for regular but not excessive communication.	Training, persistence, building into procedures processes and regularity; try weekly meetings, tailor process to business situation.	
(C) All staff kaizen	Lean engages all staff in continuous improvement.	Emergent change from all adding up to significant change. Also positive culture.	Training and engagement of staff required. Meets resistance "not my job description."	Create new employee identity and train them in simple problem solving techniques for example, 5 Whys. Assess whether to remove negative influences among staff.	

TABLE 4: Methods: selection of lean and complementary methods risk analysis table (reference case SI).

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(A) Lean methods					
5S—sift, sort, sweep, standardise, sustain	General organisation, cleanliness, and maintenance.	General efficiency and basis for on-going improvements.	Training required (to low/medium level). Needs sustainability.	Develop new culture and expectation, use visual cues, develop new identity.	
5 Whys—root cause analysis	Basic root cause analysis tool; ask why 5 times. Get to the root of the issue so it does not repeat.	Simple effective way of doing root cause analysis and simple way to get people thinking about analysis.	Training required (to low level). Once trained if not used and ideas not acted on can be a negative experience, and reason for disinterest and failure in future.	Find a mechanism to drive root cause analysis of issues/events and ask why for daily activities. Implement suggestions to get momentum and show commitment (maybe even when not ideal).	
Visual systems	Emphasis on visualisation of flow and systems of control and reporting. Part of 5s, flow and all aspects of lean. Quality at source means control is given to the worker at the source of the issue—for example, on the production line. Jidoka is the respect for humans principle which includes mistake proofing (Poka-yoke) and in cases extends worker control to even shut down the production line.	Visualises processes, makes waste visible. See other aspects, for example, 5s and Flow.	See other aspects, for example, 5s and Flow.	See other aspects, for example, 5s and Flow.	
Quality at the source, Jidoka, and Poka-yoke		Quality problems are not repeated, engagement of worker.	Training required (to medium/high level). If ignored, momentum/morale lost.	Make training a priority with key staff and then build training into daily activities. Systems for capturing ideas for poka-yoke and ensuring they get implemented.	
SMED—single minute exchange of dies (particularly beneficial to Shamrock)	Reduced setup time for machinery. Only essential internal setups made. External setups preferred to reduce downtime.	Setup time down, shorter runs possible and economically viable, enables reduced lead times and ultimately JIT. (particularly beneficial to Shamrock due to short runs).	Training required (to medium/high level). Downtime whilst working on improvements.	Make training and kaizen a priority with key staff and then build training into daily activities for others. Balance and make priorities clear (how much to spend on initiatives versus day job).	
Flexible work systems	Flexibility of employees and equipment preferred over complicated rigid or automated machinery.	Quick changeover and easily expanded systems, resources where required	Training of staff and their engagement required (to medium level). Loss of specific staff roles and responsibilities.	Communication process for change and benefits. Develop new identity.	

TABLE 4: Continued.

Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
Total productive maintenance (TPM)	Ensuring machines maintained to secure against unnecessary downtime and catastrophic failure—should incorporate continuous improvement also.	Less downtime. Health and safety improved.	Select right people, train in appropriate skills, and give understanding to staff (build new identity).	5S
	Simple tool for replenishment/pull system. Typically a card (e.g., kanban card) but could be a bin or another identifier that flags for replenishment and specifies details (supplier, qty, location). One rule of kanban is to review its size (i.e., reduce the buffer towards one piece flow as part of continuous improvement).	Links separated processes together for pseudoflow where ideal flow is not possible.	Visual systems and no shortcuts help to enforce the documented procedures.	
Just in time (JIT) manufacture. (difficult for Shamrock case)	Goods arrive just in time for processing or assembly.	WIP and lead time down, quality up.	Suggested to hold finish goods only (in production situations) or push and flow used. Both at pull of order by customer. Must be well prepared for implementation: Staff training for their understanding and engagement, other process prepared as much as possible, ready for on-going teething internally and with suppliers. Use pilot and positive staff member willing to try. Consider carefully before implementation. Level selling/marketing. Keeping buffer of finished goods to help (but not parts throughout entire system). Understand in terms of the specific business and where it is most applicable there.	Flow achieved, needs Heijunka (level scheduling)
	Level scheduling is smoothing demand—we include also takt time here which is easiest understood as average demand in time (e.g., 2 parts per minute or two quotes per day; two invoices per week).	This is key to enable JIT/one piece flow effectively without excessive idle time or overtime in production.	Lack of stability because buffers removed. Process takes much planning, training, and teething during implementation. Negative results to culture possible during teething. Again this is difficult in the Shamrock case due to the complicated jobbing processes.  Difficult in Shamrock scenarios due to high fluctuating demand, for example, job shops make-to-order and project based manufacture.	
Heijunka (level schedule) & takt time (pulse) (difficult for Shamrock case)			Flow achieved	

TABLE 4: Continued.

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(B) Complimentary Methods					
Business systems software and production control technology e.g., ERP (particularly beneficial to Shamrock)	Interactive IT databases which may incorporate algorithms for scheduling and financial management.  TOC is in itself a standalone process improvement technique with its own overarching philosophy. It identifies bottlenecks “capacity constrained resources” that need to be targeted to improve flow. Six sigma is in itself a standalone process improvement technique with its own overarching philosophy. It is most well known as a statistical method of process analysis and improvement, Six sigma can be applied as a tool within a lean philosophy.	Information collaborative reduced data entry and codification of knowledge. Particularly useful at Shamrock because of high administrative demands on complicated processes and customer requirements	Typically implementation times, culture change, and customisation requirements all extensive. Can be expensive and restrictive.	Ensure the solution is right for your environment (many may be better with simple kanban planning boards and replenishment systems). Get well prepared and ensure to have the right skill, resources, and technical support on hand.	
Theory of constraints (TOC)		Great for training and supporting flow thinking. Read the book ‘The Goal’ [62]	Does not implicitly include philosophy and culture of staff engagement and empowerment—typically consultant driven and not sustained as a standalone.	Incorporate for flow training and use as suitable as a complimentary method but be careful not to affect overarching strategy.	
Six sigma		Fine improvement of processes after basic obvious waste eliminations is made.	High level training and highly time consuming exercise to use. Workers can become too narrowly focused on statistical tools when simple problem solving is all that is required.	Use and train only as required in the meantime; use VSM and 5 whys for early results.	Other simpler methods exhausted.



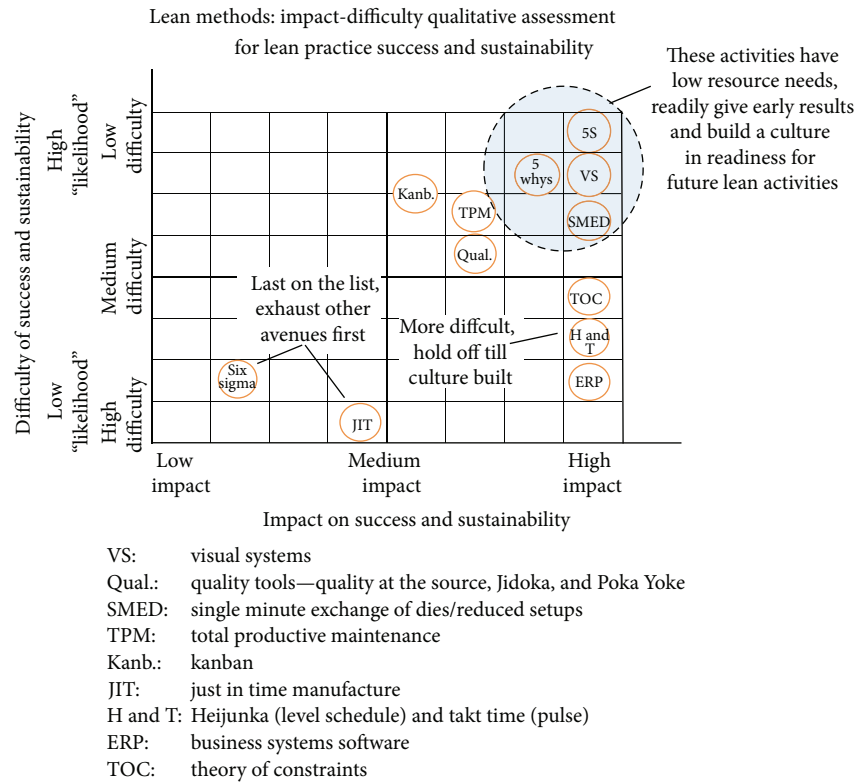


FIGURE 7: Methods: selection of lean and complementary methods with a qualitative assessment of impact and difficulty (likelihood) of success and sustainability (reference case SI).

for example, six sigma and JIT, are in the bottom left. These were assessed as particularly difficult to implement in this particular situation, and the benefits would be limited. Implementation of TOC thinking would be more beneficial than six sigma or JIT in this case. Kanban is positioned in the middle, and while (in this situation) it may not be relevant for pulling production, it could still be useful for ordering consumables. Managers and business owners at SI broadly endorsed the validity of this analysis of the situation.

**5.4. Implications for SI.** Of interest is the high impact of ERP in SI's case. This is something difficult to implement but if implemented right could have great effect. This is particularly because at SI production was partially being constrained by flow in the office. ERP implemented right would simplify quoting, planning, purchasing, and general data entry requirements which are identified as serious bottlenecks at SI (more so than specific physical production processes). It could also give other benefits such as business reporting. SI has much to benefit in understanding the holistic nature of its systems and the interaction between the factory and office processes.

Resource constraints are significant in SMEs and determine how much the organisation can achieve at any one time. In this particular case SI had just embarked on an ERP implementation that is somewhat separate from an enterprise wide lean journey. Because of the difficulty of ERP implementation our suggestion would be to hold off all other

lean initiatives (except for some higher order principles) until ERP is well achieved and the resources are freed to focus on other lean implementation activities. This also implies that if they had a clean slate and had not begun implementing ERP it may have been more beneficial to consider some of the simpler tools first. This could have benefited them with further staff engagement and built culture excellence and staff engagement before implementing ERP with its higher requirements on resources and perceived level of change.

**5.4.1. Beyond Production.** We have noted that lean has been applied effectively beyond manufacturing or production businesses. Although SI is a manufacturing business we observed they had many gains to be made in their administration centre (hence a high priority for ERP). Whether or not the physical transformation of goods took place in their own workshop there was much waste to be eliminated in their office. These lean office gains illustrate the competitive advantage of lean beyond manufacturing businesses.

**5.5. Application to Other Manufacturers.** The implications would be similar for other make-to-order, design to order, job shop SMEs, although ERP requirements may drop where products do not demand a lot of records and data entry or process control (as compared with SI's high tech and precision engineering customers).

For firms of higher production (e.g., low-variety high-volume) we would see more relevance in the emphasis on

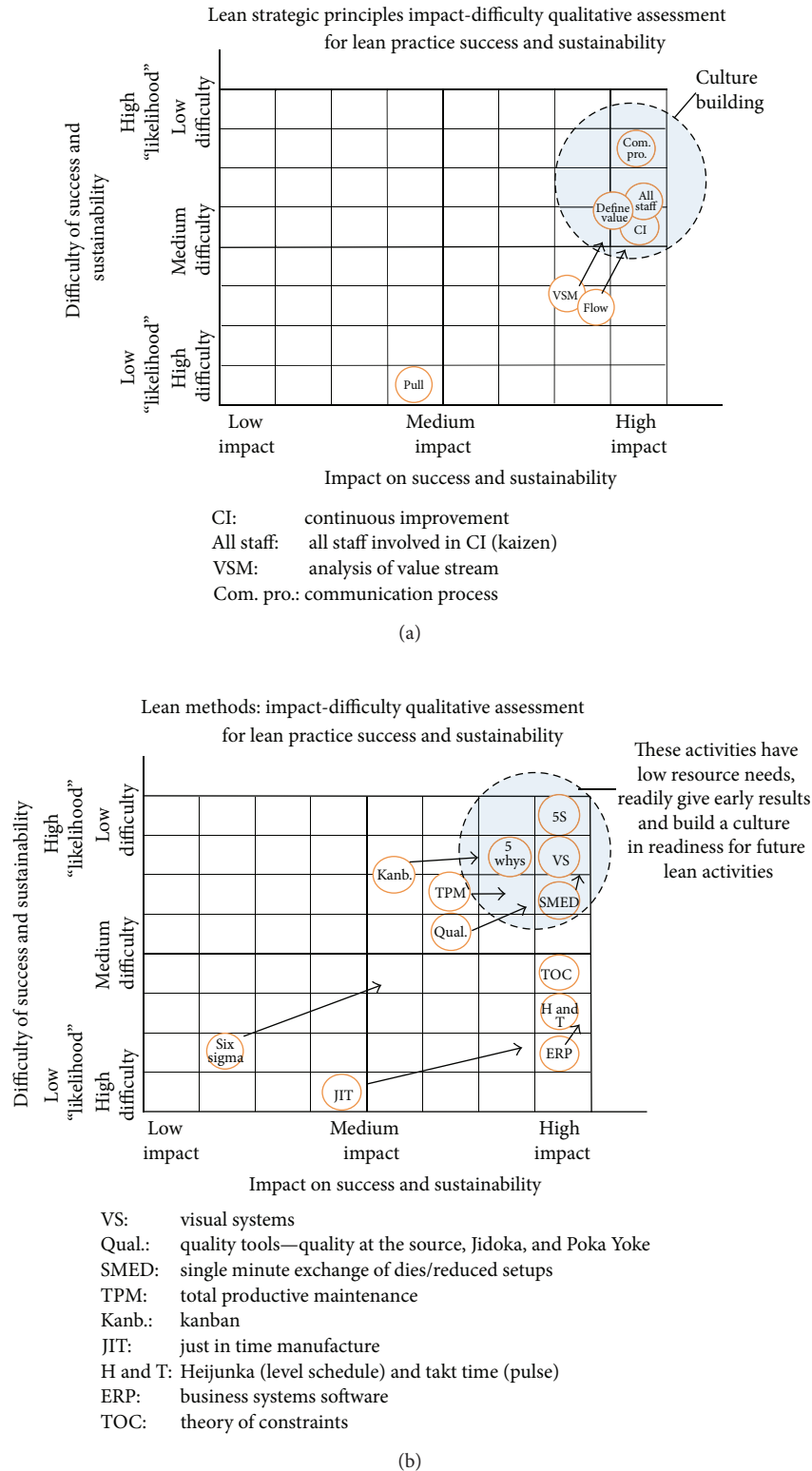


FIGURE 8: Methods and strategic principles for alternative (volume manufacture) scenario: indicative qualitative assessment of impact and difficulty (likelihood) of success and sustainability for “higher” production volumes as depicted by arrows.

process flow principles and tools. We have illustrated these and other likely changes by placing arrows overtop of the previous charts; see Figure 8.

## 6. Discussion

**6.1. Outcomes: What Has Been Achieved?** This work encompasses lean thinking and methods, lean implementation, organisational change, and risk management. Exploring the literature at the intersection between risk management and lean transformation we found no application except for piecemeal usage of methods and aspects of lean loosely tied to risk. There was little evidence of risk management and lean implementation being integrated by practitioners.

The present work makes several novel intellectual contributions. The first is methodological, in that it demonstrates a way to integrate risk management into decision making when implementing lean. This method makes the detriments (the threat component of the risk) more explicit and therefore amenable to treatment. The method achieves a high level of integration between the two management methods. We did this by comparing lean management with risk management as codified in the ISO standard [35] and developing a common framework with lean.

A second contribution is that the method provides a way to explicitly identify the organisation difficulty of implementing lean practices. This is important, because although these organisational difficulties have previously been identified in general terms (e.g., the lean iceberg model), it has up to now been difficult to determine how those apply to specific situations. Thus variables that were once general situational variables (or contingency factors to use the change management term) can now be included in the decision-making. The method, while not specifically providing a temporally phased approach to lean implementation, encourages the decision-maker to explicitly evaluate which lean methods are relevant to the organisation at the time under consideration.

The third contribution is that we have piloted a method for applying lean to organisations other than high-volume manufacturers. In particular, the method was developed in a challenging type of organisation: an SME involved in high-variety low-volume manufacturing. This type of organisation has otherwise found it difficult to implement lean, as seen in the late adoption. The method and the case study bring out implications and provide solutions that could be relevant to other types of organisation too. The case study showed that it is possible, given contextual knowledge of the organisation, to predict which lean methods are most important in the setting. This enables the prioritisation of organisational effort, something that is relevant to all organisations but particularly to SMEs with their limited resources for such endeavours.

A fourth contribution is that we have now built another conceptual component in a model for high-value manufacturing. This is of national strategic importance to small countries like New Zealand, whose manufacturing industries cannot easily compete with other countries that have low labour costs and high production volumes. We suggest that intelligent implementation of lean is necessary for high-value

manufacturing and is complementary to strategic decision making regarding manufacture [3] and environmental considerations [61], among others.

**6.2. Implications for Practitioners.** For practitioners, that is, those managers in organisations that are considering what parts of lean to implement, the primary implication is that they should not only focus on the high impact lean methods but also consider a staged approach. We recommend they deliberately select lean methods that will build lean culture through small wins and staff engagement, before progressing to more overly lean methods. Lean implementation involves a transformation of the organisation, and initially the journey (i.e., the human dimension of the change process) is as important as the destination.

In making the decisions about lean, our suggestion is that managers consider applying the method given here, by evaluating the impact of each of the lean principles and tools and the difficulty of implementing them *in that specific organisational context*. We suggest that the organisational context is very important, and that the analysis is best done by someone who has deep understanding of how the organisation operates. At the same time it is also important that the analyst understands the capabilities of the various lean principles and tools. In this paper we have only identified these by name, as a full description would overwhelm the present paper. However we recommend practitioners gain the necessary lean knowledge by consulting one of the many excellent texts or employing an expert.

Another implication for practitioners is that the method we propose here is closely aligned to the risk management method. Consequently there should be no impediment to including the lean risk assessment alongside other risk management practices. Alternatively, if the risk management framework [35] is not already part of the organisation's practices, then we would suggest that consideration should be given to exploring that too, since it is not much more effort than to do so. The management approaches are complementary and mutually supportive having synonymous principles, framework, and process.

**6.3. Limitations and Implications for Further Work.** A limitation of this work is that the case study was more of a cross-sectional rather than longitudinal design and on only one firm. This naturally limits the external validity (limits the ability to generalise to other situations). It would be interesting to apply the method to a firm or multiple firms over time to assess how well the predicted lean methods actually performed and how decision making priorities adjust in time.

Another limitation is that the analyst needs both contextual knowledge of the firm and knowledge of the lean methods. We have explicitly identified that need in our recommendations to practitioners. It would be interesting to know just how much knowledge practitioners really have about lean. The root of failed implementations of lean might be ignorance, which would also limit our method. It would be interesting to do a widespread survey of the

extent of lean knowledge and check whether that causes poor implementation.

## 7. Conclusions

The objective of this work was to explore how risk management methods are applicable to and supportive of lean implementation success. Risk analysis and management are critical to all serious decision making processes. However there has been little to no documented application or study of risk management in the lean implementation field. We have shown that it is possible to integrate risk management and lean management. We further developed a qualitative method where lean tools may be prioritised for a specific organisational setting. We applied this method to a case study. The case study provided implications for similar high-variety low-volume manufacturers as well as alternative operation modes (e.g., low-variety high-volume manufacturing, service organisations, and administration). The ongoing efficacy of lean tools and methods is very much dependent on the situational variables of the organisation. We believe that each aspect should pass through a risk assessment and analysis of some kind to determine treatments necessary. Our approach focused on treating lean failure by prioritising the tools that not only will deliver performance gains but also are culture building.

## Authors' Contribution

All authors contributed to the conceptual and intellectual development of the ideas in this work and to their expression in this paper. Antony Pearce performed the detailed lean risk assessments and spent the time embedded in the case study firm.

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